INNOVATIVE ELECTROSTATIC ADHESION TECHNOLOGIES

(Flexible Electrostatic Tools for Capture & Handling [FETCH])

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Background

Capture is quite difficult for Orbital object handling and satellite servicing:

- Most satellites and upper Stages are not designed for docking, refueling, and Disposal
- Billion dollar satellites become inoperable due to fuel depletion
- Thousands of abandoned Satellites, spent Upper-stages and discarded structures create daily threats to operational Satellites, ISS, Exploration
- New Capture technology will impact hundreds of existing satellites in service by extending mission lifetimes and allowing handling of threatening derelict orbital objects

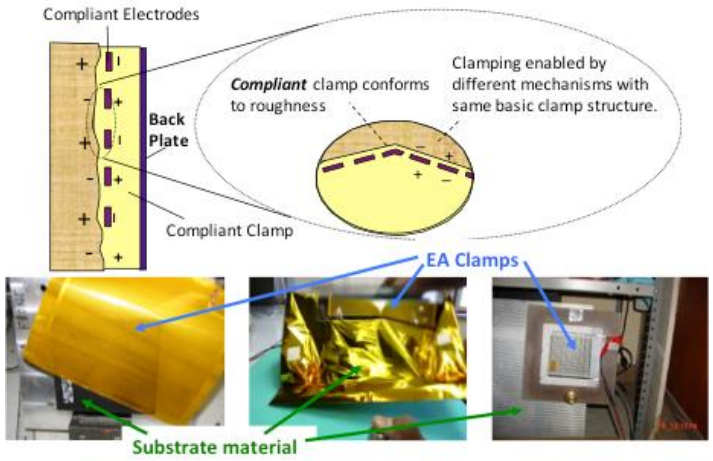
The Challenge:

Conventional robotic arms and grippers have difficulty finding suitable capture structures

The Answer: **Electrostatic Grippers**

Why Explore Electrostatic Grippers?

1. Able to grip and release various materials on command
2. Able to conform to different surfaces due to flexibility
3. Fewer moving parts, potential to be more reliable

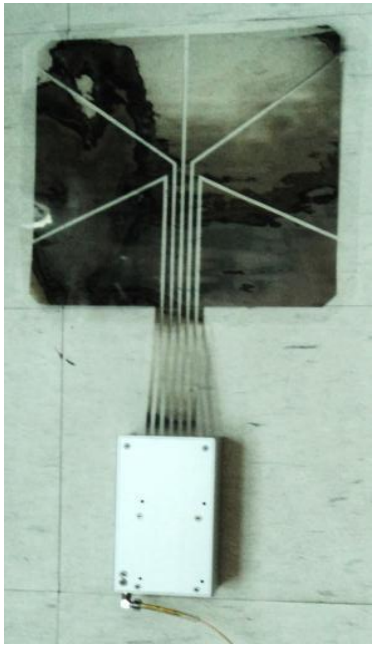


Innovative Technology – Electrostatic Adhesion

Modes of Manipulation

	Pull	Shear	Twist
Sheet Metal	Poor	Exceptional	Exceptional
Painted Metals	Poor	Inconclusive	Inconclusive
Photovoltaics	Poor	Inconclusive	Inconclusive
MLI	Poor	Exceptional	Exceptional
Kapton/Mylar	Poor	Effective	Effective
Wood	Poor	Poor	Poor
Paper	Effective	Effective	Effective

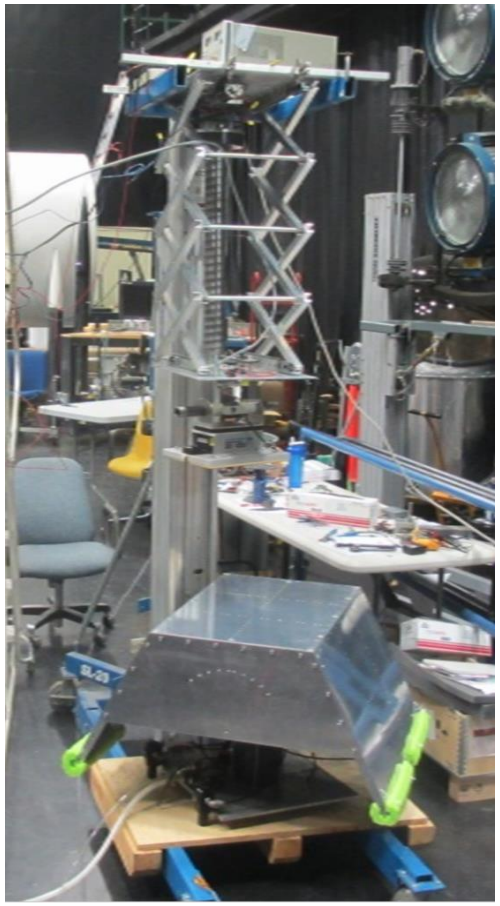
- Results of testing using ElectroGrip© 11.5” x 11.5” DR5 Electrostatic chucks
  - 2-4kV high Voltage range with 6 poles & 3 phases
  - Close Proximity Sensing up to about ½ meter
- 3-phase gripper performance increases marginally in low moisture @ 1 atm. (from 51% RH vs. 0.1% RH at 68ºF)
- Toggling down period of voltage cycling rate from quick to slow induces notable stronger Johnsen-Rahbek attraction effect



ES\EA grippers by ElectroGrip, Co. and GrabIt, Inc

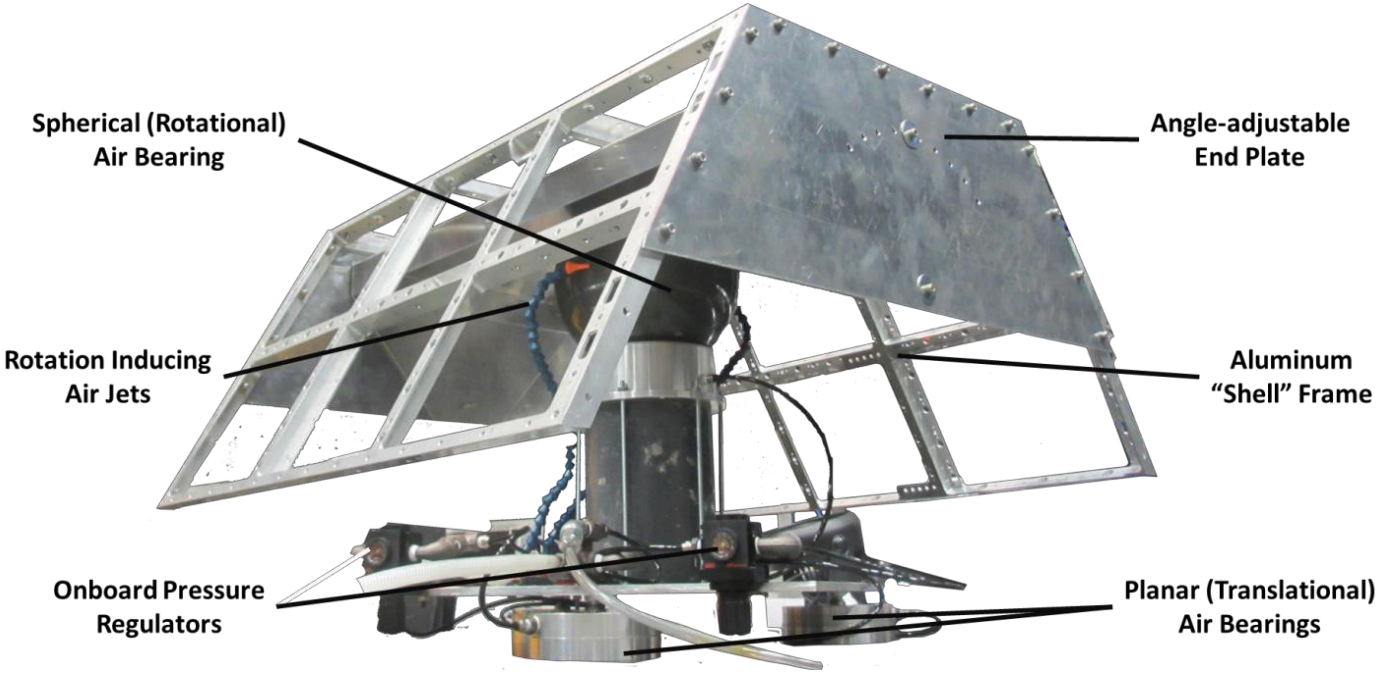
Technology Development

To **use** the Innovative gripping capability of Electro-Static Adhesion to Capture Unstable Satellites and Orbital Objects, we need a retractable boom that allows the retrieval vehicle to observe from a safe stand-off distance and extend and synchronize the flexible ES Gripper with the unstable object's center of rotation to grip with minimal impact and use its grip to de-spin before moving the object toward the retrieval vehicle by boom or releasing and re-capturing it.



Proof of Concept Ground Testing
(On MSFC Flight Robotics Lab Flat Floor)

Re-Active (Unstable) Satellite Simulator: To evaluate the planned capture mechanism and methodology, a 5-axis air-bearing simulator was built that can support various simulated spacecraft surfaces at different angles and spun up by de-coupled air jets. Misalignments between the ES Gripper and the simulator will result in relative motion or gripping failure. A collection of optical pointers, smart cameras and lidars will be tried.



Conclusion

- Electrostatic grippers are able to interface with conductive and nonconductive materials
- Highly finished surfaces (e.g. sheet metal) provide better gripper—object contact for less static charge loss, provides greater grip force
- Electrostatic grip strength increases with the square of voltage
- Shearing & twisting operations are more effective modes of manipulation than normal pull
- Greater risk of gripper peeling and detaching with normal pull operations, believed to be related to mounting configuration
- Docking simulations on frictionless flat floor conclude the electrostatic robotic end effector as a viable primary contact/capture arm, with a secondary robotic arm to perform servicing operations